Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

Canada Alberta

89-01401/

The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

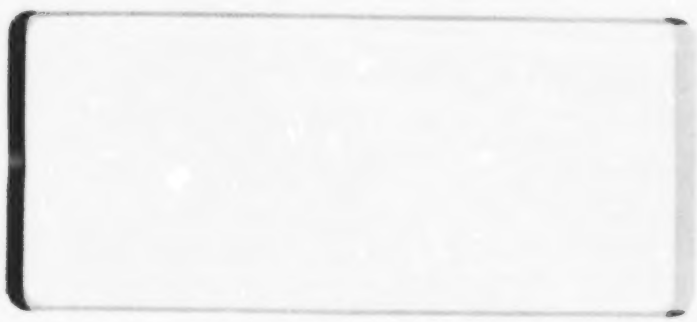
The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

L'Entente comprend trois programmes: Reboisement; Recherche appliquée, transferts de connaissances techniques et relevé des occasions; et Information, évaluation et administration. Ces programmes sont gérés par un Bureau de direction conjoint, et mis en oeuvre par le Service canadien des forêts et le Service forestier de l'Alberta.



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ALBERTA ASPEN VS. BLACK POPLAR WOOD QUALITY DIFFERENCES

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1987

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DISCLAIMER

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INTRODUCTION

Aspen (Populus tremuloides) is accepted raw material of the waferboard and oriented strandboard industry both in the United States and Canada. From the standpoint of better utilization of Alberta Forest Resources Balsam Poplar (Populus Balsamifera) is a logical supplement to Aspen waferboard or oriented strandboard furnish because it is the most abundant species in the Aspen forest type. However, according to reports presented to the 1980 Canadian Waferboard Symposium, even small quantities of Balsam Poplar contribute to major problems in waferization, gluing stability and consequently, panel product quality.

This study attempts to identify and evaluate the major anatomical, chemical and physical wood quality parameters between Aspen and Balsam Poplar in an attempt to understand the Balsam Poplar's potential as a raw material for waferboard and oriented strandboard panel industry.

The first progress report summarized the preliminary results of an ongoing project on WOOD AND PRODUCT QUALITY; Phase I: WAFERBOARD/ORIENTED STRANDBOARD from ASPEN/B.POPLAR. The major emphasis during the reporting period was given to the determination and evaluation of differences in anatomical structure, fibre and cell dimensions and dimensional changes of both studied species.

The second progress report focused (in addition to continuation of analyses of anatomical and growth quality parameters) on chemical composition of Aspen and Balsam Poplar (Lignin, Cellulose, Hemicelluloses and Extractives).

The final report combines the anatomical, physical, and chemical differences which may together influence panel manufacture data and variation board properties.

MATERIAL AND METHODS

1.0 The Samples

Six breast-height disks of aspen and balsam poplar trees were cut from forests in the Slave Lake area. Six disks of tree tops each were also harvested. The basal disks of the two species were arranged from large to small diameters and designated as Tree 1 to 6 in sequence. Radii along the long and short axes of the disks as well as the bark thickness along the axes were measured and recorded. For comparison the dimensions of the basal disks are presented in Figure 1.

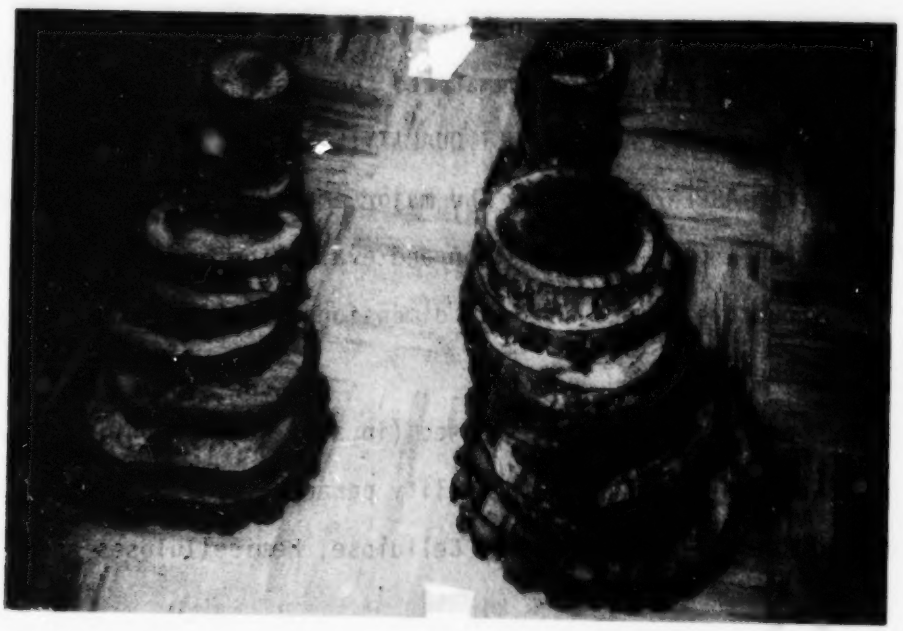


Figure 1. The size variation of basal disks for aspen and balsam poplar

2.0 PHYSICAL PROPERTIES

2.1 Shrinkage and Swelling Measurements

Wood blocks were sawn from sapwood and heartwood regions of each disks. The blocks were further shaped into orthotropic wood cubes with well aligned cross, radial and tangential surfaces. Two cubes from the sapwood and heartwood of each tree were prepared. The surfaces of the cubes were trimmed with razor blade to be as true as possible. The cubes were stored in sealed weighing bottles to preserve moisture. The original weights of cubes were measured. The length, width, and height of each cube were carefully measured with a micrometer to 1/1000th of a millimeter. The cubes were then placed in petri dishes dried in oven at 60°C for 30 minutes. At the end of the period, each cube was transferred to a weighing bottle and capped to arrest moisture change. The new weights and dimensions of the cubes were carefully remeasured. The process was repeated until moisture content remained constant. The cubes were placed in a 100°C oven for 2 hours to establish the oven-dry weights and dimensions. Subsequently, the cubes were put in a desicator with saturated relative humidity for moisture resorption. The new dimensions and weights were recorded. Finally, the cubes were put in a beaker and weighed under water and vacuum were applied to aspirate the air out, after five days the cubes were completely water-logged. The reswelled dimensions and the maximum-moisture content weights were measured. The dimensional changes with respect to the original green sizes were calculated as percentage shrinkage.

2.2 Wood Properties Variation with Respect to Tree Age

A wedge-shaped sector was sawn from each sample disks along radius intermediate between the long and short axes. As oblong disk shape and

eccentric pith often indicate tension wood formation, the wedges were cut from such positions to avoid sampling tension wood excessively. The surfaces of the wedges were trimmed with razor blades. Growth increments from 0 - 5, 6 - 10, 11 - 15, 16 - 20, 21 - 25, 26 - 30, and every 10 years thereafter to 60 years, and every 20 years thereafter to the bark were marked into sections. Growth rate variations of the fastest and slowest growing trees (Tree 1 and 6) of each species were also analyzed with Digi-Mic, a tree ring analyzer. (Figure 2)

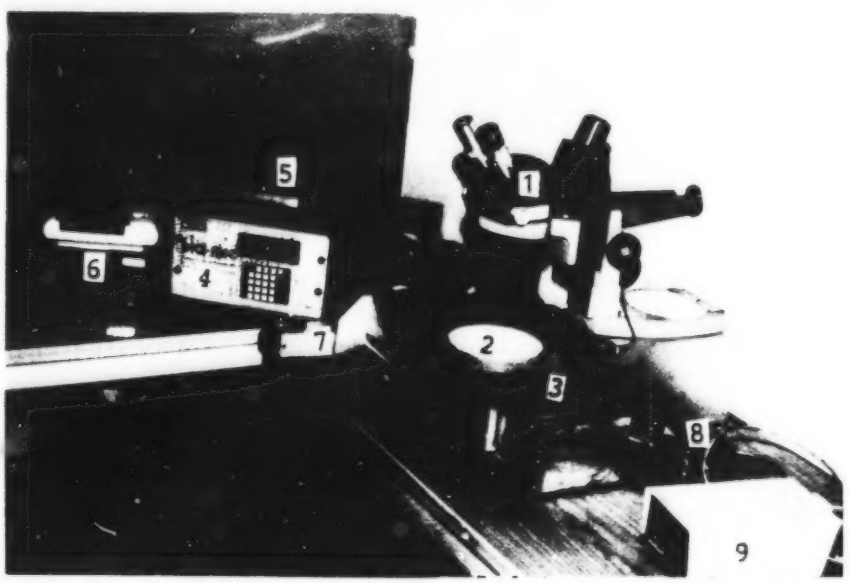


Figure 2. Digi-Mic system (1) microscope, (2) sample disk, (3) movable carriage, (4) micro-processor, (5) cassette recorder, (6) additional transmitter, (7) remote control, (8) pin type switch box and (9) modem for DECwriter/mainframe computer.

2.3 Cell Dimensions

Wet wood slivers were peeled from the 5th, 10th, 15th, 20th, 30th, 40th, 60th, 80th, 100th, and the outermost rings of Tree 1 of both aspen and balsam poplar. Composite samples of wood slivers from rings 11 - 15, 31 - 40, and 80 - 100 of all other trees were also prepared. The slivers were put in glass vials and maceration solution consisted of 1:1 acetic acid and 30% hydrogen peroxide was added to each vial. The contents were allowed to digest at 60°C for 24 hours. The liquor was then aspirated off and after washing, shaken to separate the cell elements. Wad of fibers were then collected, stained and mounted with glycerine on a special sampling slide. The projected images of fibers and vessels from the slide were measured with digitizer-computer to obtain mean fiber and vessel length, as well as vessel width.

The computerized cell dimension measurement technique has been developed at the University of Alberta. The system makes use of standard computer components to measure fibres, record measurements and make calculations. Components used are: a magnification projection unit, a graphics tablet, a hand-held, four-button cursor, a graphics tablet controller, a desk-top computer and a hard copy unit. An illustration of the system described above is shown in Figure 3.

3.0 CHEMICAL PROPERTIES

One sector of each quarter of the disk was used for chemical analysis and swelling measurements. After saving a portion for swelling tests, the remainder of each sapwood and heartwood zone were reduced to wood meal separately. The specimens were clamped in a vice and fragmented with a wood file. The wood meal was sorted and air-dried.

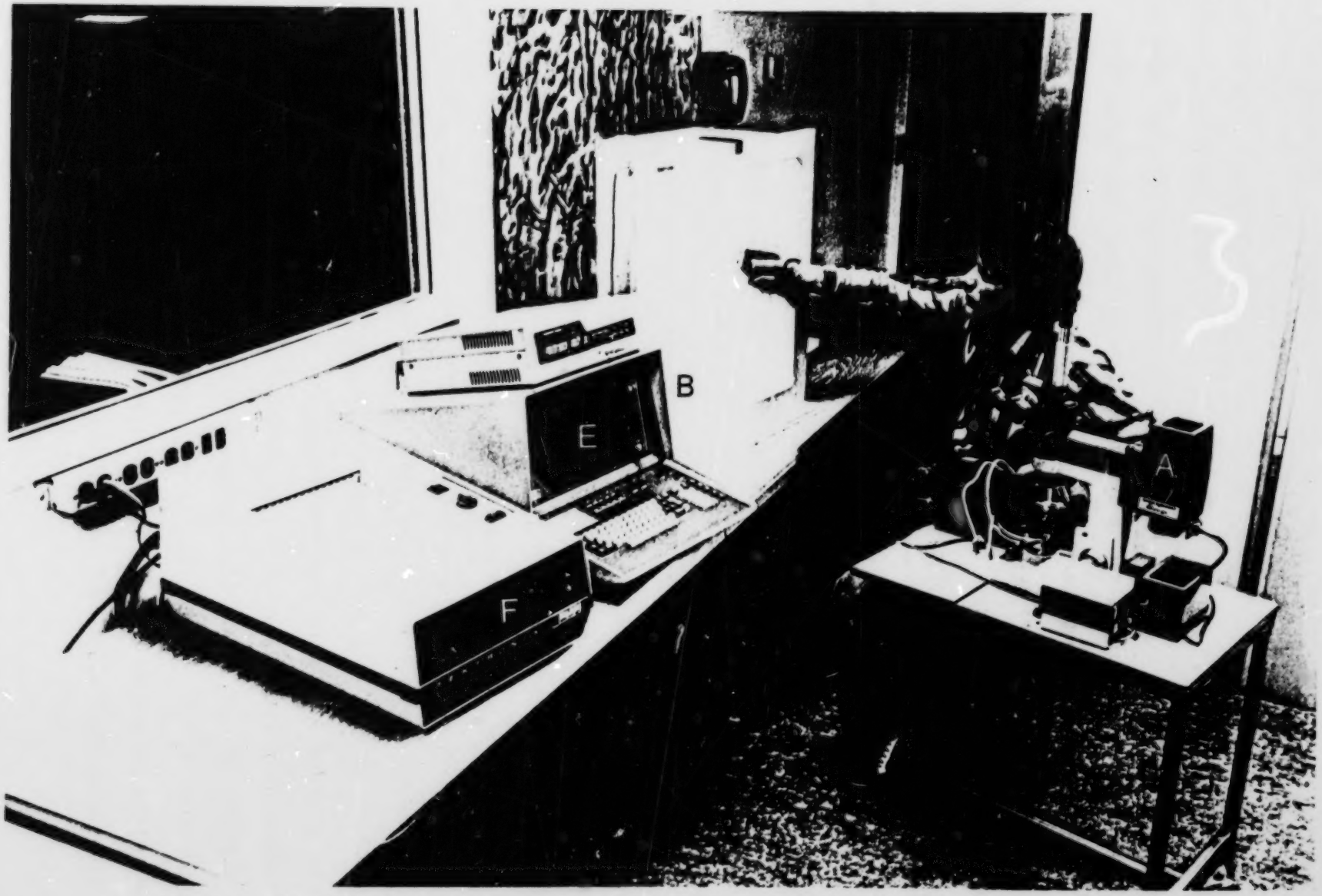


Figure 3. The Computerized Measurement of Wood Fibre, Vessel and Other Cells Dimensions

3.1 Extractive Content

A know quantity of wood meal, roughly 7 to 10 g was placed in a paper thimble and extracted with (1:1) mixture of alcohol an benzene solvent, using a Soxhlet apparatus. After 24 hours, extraction was complete. The wood meal was dried in an oven at 103±°C. The samples were re-extracted subsequently with petroleum ether. The extracts from each sample were distilled separately and evaporated to dryness. The extractive contents were calculated based on extractive-free, oven-dried wood meal. The extractive free wood meal was used subsequently for the estimation of hollocellulose content, Cross and Bevan cellulose, Klason lignin, 1% HaOH solubility and ash content analyses.

3.2 Holocellulose

Extractive-free wood meal (1.0 g,o.d.) was placed in an Erlenmeyer flask and 200 ml of glacial acetic acid was added. The content of the flask was shaken occasionally to allow thorough penetration of the acid. Sodium chorite crystals were added to the flask in several installments to keep the reaction going. The flask was warmed in a 60°C water bath for 24 hours. The crude holocellulose was filtered over a Buchner funnel, washed sequentially with distilled water, 1% NaOH, acetone and finally with distilled water. The content was then oven dried at 103±°C, colled in desiccator, and weighed to one-tenth of a milligram. The holocellulose content was calculated based on extracted, moisture-free wood.

3.3 Cross and Bevan Cellulose

The holocellulose obtained above was placed in a beaker and 200 ml 1.3% sulphuric acid was added. The content was allowed to hydrolyze for 2 hours

and boiling water bath. The fiber suspension was filtered through a sintered glass crucible, and the residue was washed with water, ethanol, and diethyl ether. After drying in the oven at 103±°C, the Cross-Bevan cellulose content was calculated based on oven-dry weight of extractive-free wood.

3.4 Lignin Content

Extractive-free wood meal (0.5 g) was placed in a beaker and 15 ml 72% sulphuric acid was added. The mixture was stirred constantly and allowed to stand for two hours with occasional stirring. The content was then transferred to a larger beaker and diluted with water to 3% sulphuric acid concentration. The solution was boiled for 4 hours with liquid maintained at constant level. After filtering over a sintered glass crucible, the residual lignin was washed, oven-dried and weighed. Yield was calculated based on dry weight of extractive-free wood meal.

3.4 Sodium Hydroxide Solubility

Extractive-free wood meal was boiled with 1% HaOH at constant liquid level for 1 hour and the residue was filtered washed and oven-dried. One percent sodium hydroxide solubility was calculated based on moisture-free material.

3.5 Ash Content

Known quantity (1.00 g) of wood meal was transferred to a porcelain crucible and muffled in a furnace at charring temperature. Later on, the temperature was maintained at 600±°C for 3 hours. The content was cooled in a desiccator and weighed to one-tenth of a milligram. Ash content was calculated based on dry sample.

3.6 Mineral Contents

Ashes from the un-extracted, alcohol-bezene extracted, petroleum ether extracted, and 1% NaOH extracted wood meal were kept in porcelain crucibles. One ml of concentrated hydrochloric acid was added to each crucible to dissolve the mineral. Reaction was allowed to proceed for 1 hour. The mineral solution was diluted with 4 ml de-ionized water and filtered. The crucible was then rinsed with 5 ml de-ionized water. The undissolved, refractory residue in the crucible was weighed after drying.

RESULTS AND DISCUSSION

The dimension of breast-height disks of aspen (A) and balsam (B) trees are summarized in the following Table:

Table 1. Disk Diameters and Bark Thickness of Aspen (A) and Balsam (B) Poplar Trees.

Tree Number	Disk Diameter, cm		Bark Thickness, cm	
	Short Axis	Long Axis	Short Axis	Long Axis
A-1	27.2	32.0	1.5	3.2
A-2	24.5	25.1	2.3	1.6
A-3	21.7	24.0	1.2	2.3
A-4	18.8	21.3	1.9	2.1
A-5	18.7	20.0	2.2	2.1
A-6	18.4	20.7	2.2	1.5
B-1	31.0	36.4	3.8	4.6
B-2	25.9	29.8	3.5	3.2
B-3	25.7	28.4	1.7	3.2
B-4	22.5	25.0	2.2	2.8
B-5	21.2	23.3	2.3	2.6
B-6	20.3	20.7	3.2	2.7

The measurement of shrinkage/swelling resulted in an interesting observation on the differences on shrinkage/swelling rates of sapwood and heartwood. Heartwood on the average has higher shrinkage/swelling values than the sapwood for both species. The differences in volumetric(V), Radial(R), Tangential(T) and Longitudinal(L) shrinkage for both species are demonstrated in Table 2.

Table 2. Example of L, T, T and V Shrinkage of Aspen(A) and Balsam Poplar(B)

Sample Code	Shrinkage, %			
	V	T	R	L
A-1 Sapwood	14.05	8.68	4.65	1.29
A-5 Heartwood	17.03	9.74	6.72	1.45
B-1 Sapwood	11.11	7.61	3.38	0.42
B-6 Heartwood	16.15	10.48	5.72	0.65

The growth rate variation of the fastest and slowest trees of each species (A-1, A-6, B-1, B-6) were analyzed with the Digi-Mic ring analyzer. The growth rate variation of aspen is demonstrated in Figure 4. Figure 5 represents the growth rate variation of balsam poplar.

The moisture content distribution in both species varies significantly. The range and variation of moisture with the age of the tree is demonstrated in Figure 6. Many balsam poplar trees have much higher moisture content in the heartwood zone than in the sapwood. The differences for aspen are not as great as in balsam poplar. The differences for aspen are not as great as in balsam poplar. The poplar showed signs of the "wet heart" which may be caused

Fig. 4 GROWTH RATES VARIATION AMONG ASPEN TREES

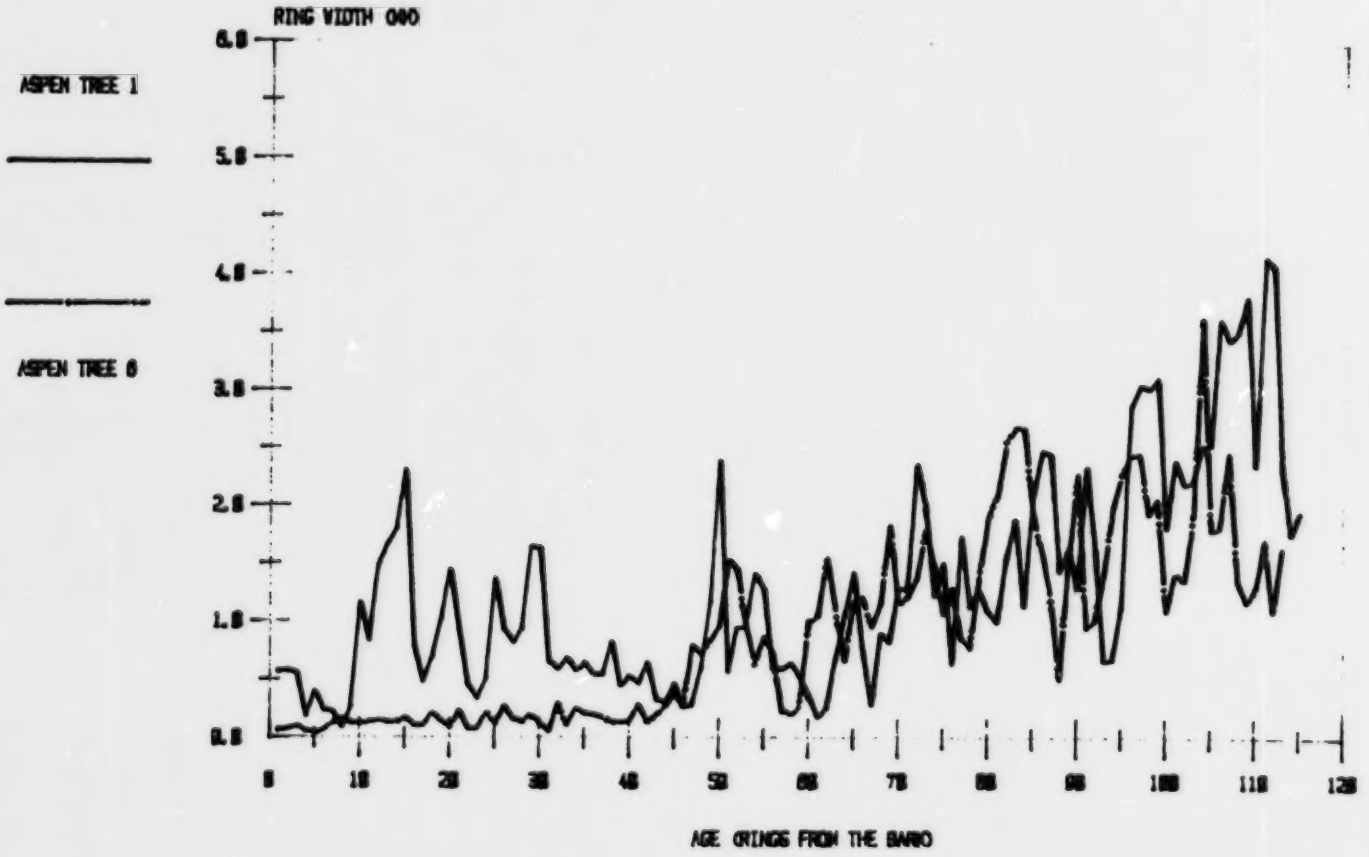


Fig. 5 GROWTH RATES VARIATION AMONG POPLARS

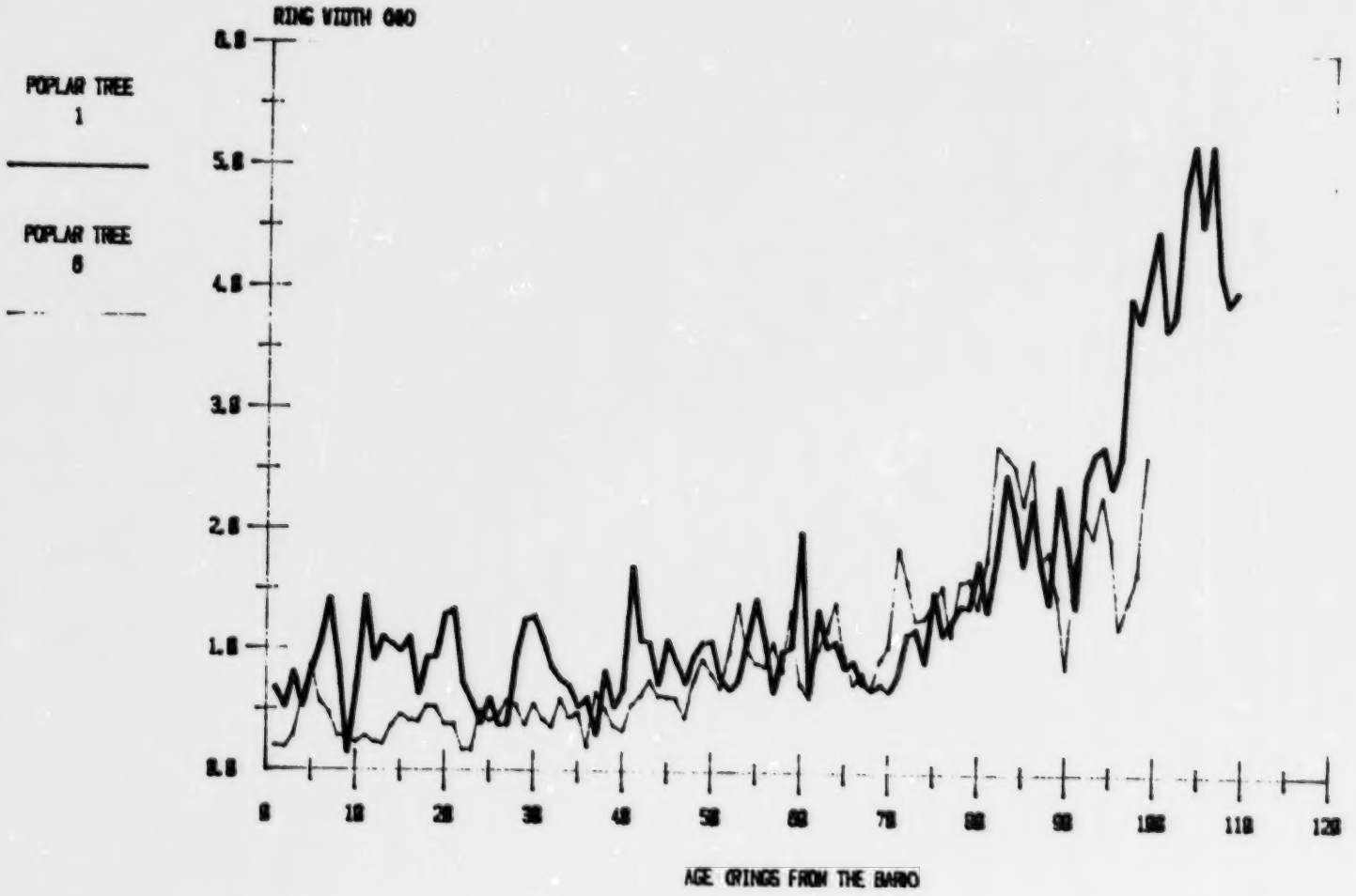
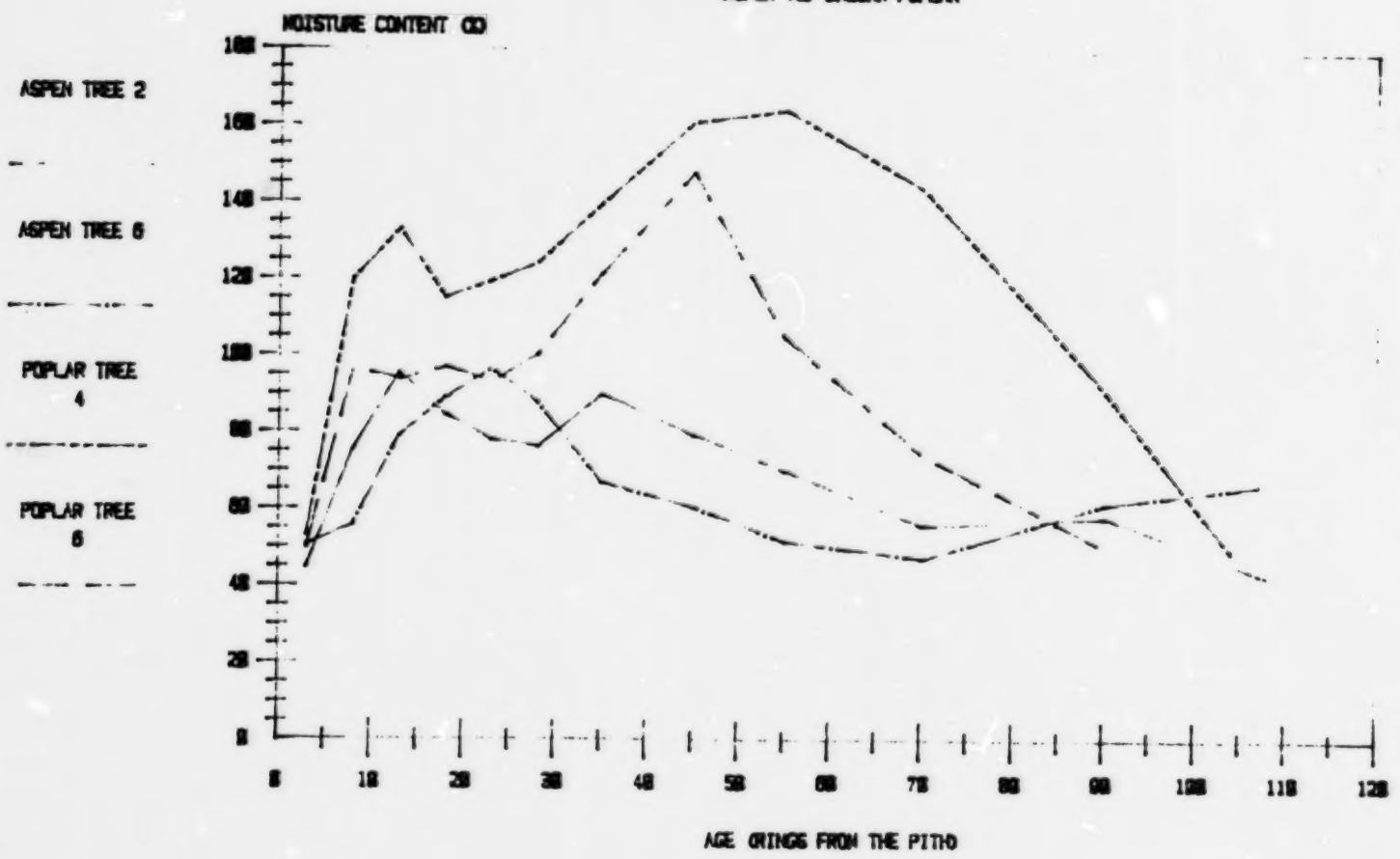


Fig. 6 MOISTURE CONTENT DISTRIBUTION COMPARISON



by bacterial attack and consequently, the wood tissue may be degraded to some extent causing weakness in strength and rough and fuzzy surface of wafers during waferization process. This phenomenon will be investigated in more details and reported in the second year of this ongoing study - PHASE II.

The measurement of cell dimension of aspen and balsam poplar and distribution of cells also demonstrates the differences in texture of both species. Many samples of aspen and balsam poplar from juvenile and mature wood sections were macerated and the mounted sampling slides are being prepared. Preliminary data available at this time indicates that the balsam poplar has somewhat wider vessels than vessels in aspen contributing to the coarser texture and lower density of balsam poplar. The demonstration of this phenomena is presented in Figures 7 and 8. Statistical data to support the significant differences in the width of vessel element in aspen and balsam poplar based on 30 vessel-width measurements are presented in Tables 3 and 4.

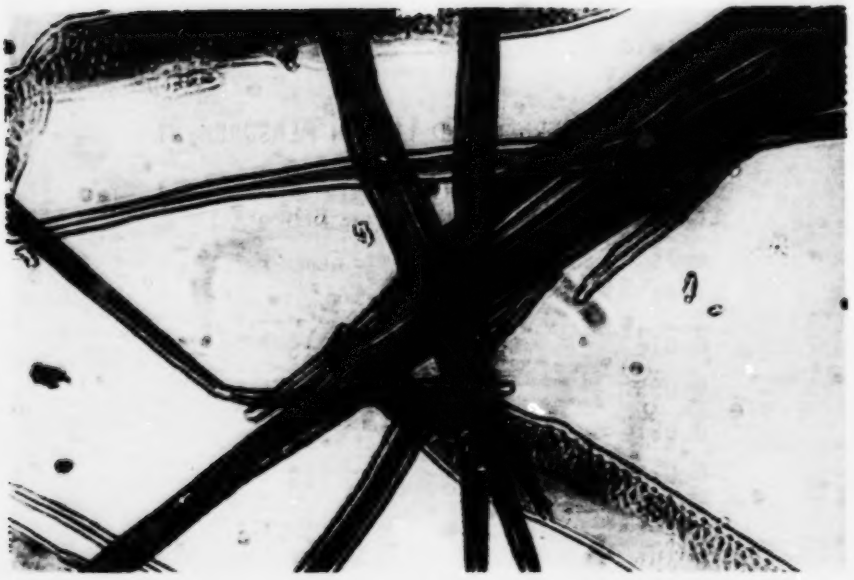


Figure 7. Aspen Mature Wood Fibres and Vessels.

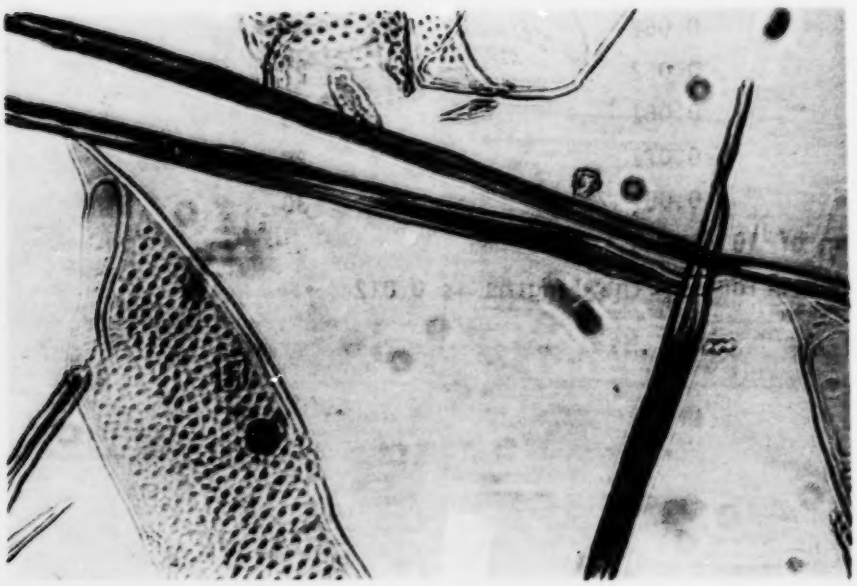


Figure 8. Balsam Poplar Mature Wood Fibres and Vessels.

Table 3. Demonstration of Aspen Vessel Width Measurement/Variation

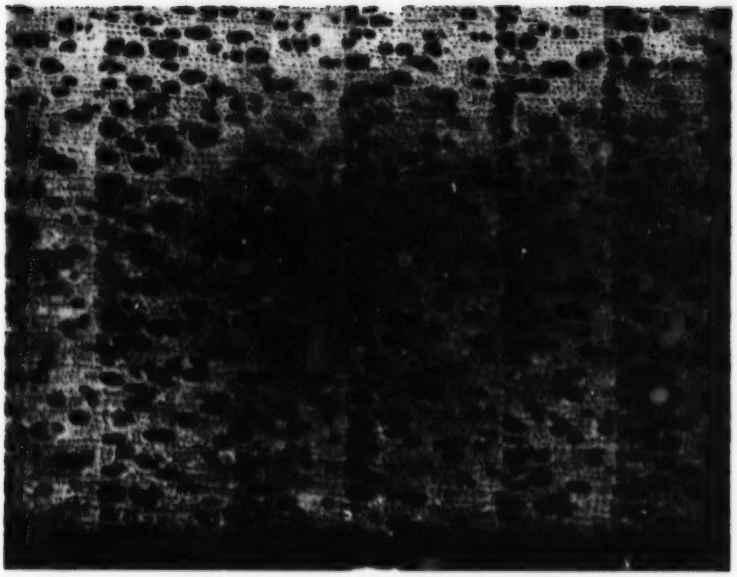
Slide I.D. - A1-30-veswid.

FIBRE DISPLAY AND LENGTH MEASUREMENT

Fibre number	Length mm's	Fibre number	Length mm's
1	0.016	16	0.082
2	0.055	17	0.057
3	0.051	18	0.051
4	0.077	19	0.065
5	0.070	20	0.052
6	0.051	21	0.082
7	0.080	22	0.049
8	0.066	23	0.067
9	0.087	24	0.058
10	0.059	25	0.056
11	0.052	26	0.061
12	0.052	27	0.050
13	0.061	28	0.044
14	0.077	29	0.051
15	0.057	30	0.071

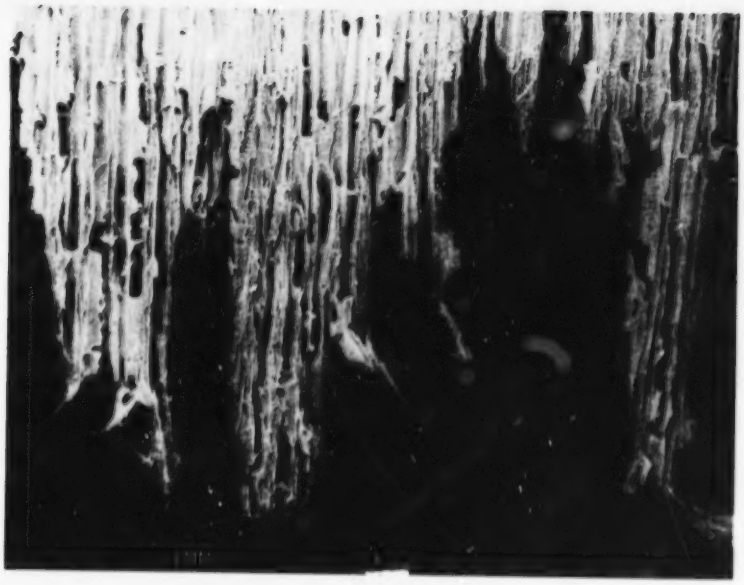
Length mean of 30 fibres - 0.061 mm

Standard deviation for the lengths is 0.012

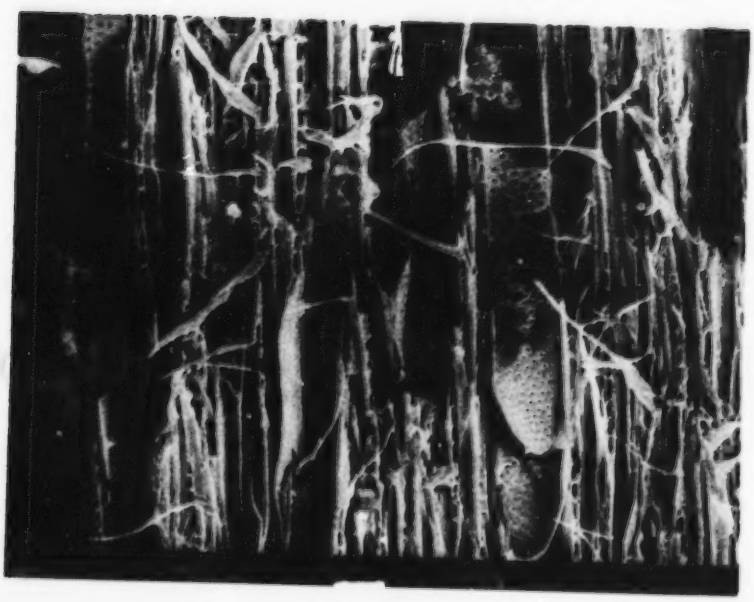


Picture 1. Scanning Electron Micrograph of
B. Poplar Cross-Section.

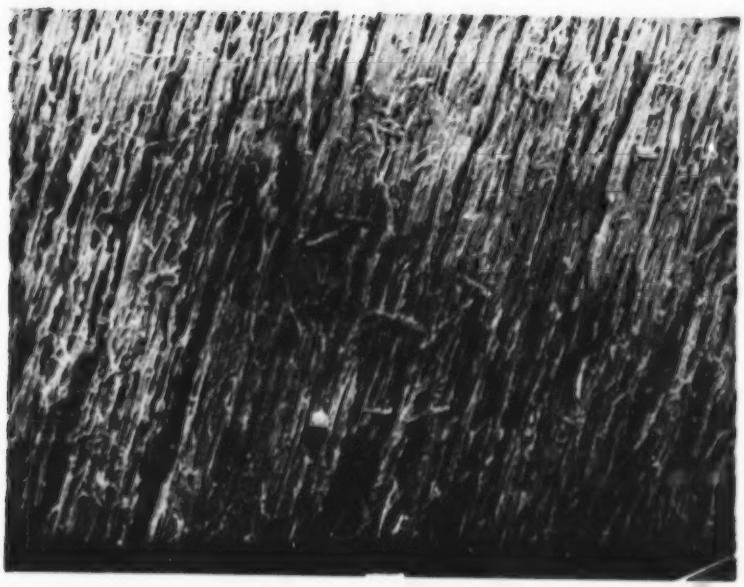
Picture 2. Scanning Electron Micrograph of
B. Poplar Wafer Surface.



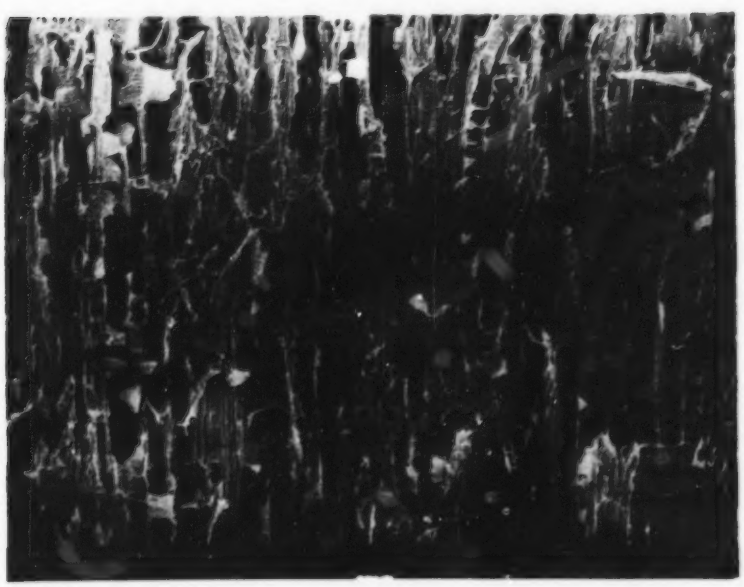
Picture 3. SEM Edge of Wafer.



Picture 4. SEM Wafer Surface.



Picture 5. SEM Wafer Surface of Aspen



Picture 6. SEM Wafer Surface of Aspen
(Higher Magnification)

Table 4. Demonstration of Balsam Poplar Vessel Width Measurement/Variation

Slide I.D. = B4-30-veswid.

FIBRE LENGTH AND LENGTH MEASUREMENT

Fibre number	Length mm's	Fibre number	Length mm's
1	0.108	16	0.060
2	0.167	17	0.102
3	0.128	18	0.139
4	0.143	19	0.139
5	0.106	20	0.096
6	0.129	21	0.110
7	0.102	22	0.142
8	0.099	23	0.158
9	0.095	24	0.082
10	0.140	25	0.092
11	0.076	26	0.127
12	0.081	27	0.133
13	0.115	28	0.095
14	0.080	29	0.094
15	0.069	30	0.135

Length mean of 30 fibres = 0.111 mm

Standard deviation for the lengths is 0.027

In addition to statistical analyses on fibre length, vessel size (vessel segment length as well as vessel segment diameter) for aspen and B. poplar, the scanning electron microscope data collected given in Scanning Electron Micrograph pictures 1-6. Scanning electron microscope pictures of wood sections as well as wafer surfaces indicate the formation of fines during the waferization process. Consequently, the surfaces of waferized Balsam Poplar seems to be rough and fuzzy.

Differences in chemical analyses of aspen and balsam poplar and distribution of major wood components (Holocellulose, cross and bevan cellulose, lignin and ash content) in different part s of the tree, specifically in the bark, sapwood and heartwood, is given in Table 5. Sodium hydroxide solubility of bark component, sapwood and heartwood is also included in Table 5. Extractives in various extraction agents such as alcohol/benzene mixture, petroleum ether and also wafer are summarized in Talbe 6.

Table 5. Chemical Analyses of Aspen and Balsam Poplar Wood Components.

	BALSAM POPLAR %	ASPEN %
I. Hollocellulose		
Bark	69.57	65.91
Sapwood	80.18	84.48
Heartwood	84.04	87.10
II. Cross and Bevan		
Bark	42.60	40.10
Sapwood	66.20	65.20
Heartwood	68.72	68.81
III. Lignin		
Bark	28.02	22.43
Sapwood	20.39	16.31
Heartwood	17.20	19.20
VI. Ash Content		
Bark	7.98	4.99
Sapwood	0.92	0.66
Heartwood	1.89	1.20
1% Sodium hydroxide solubility		
Bark	30.63	23.27
Sapwood	14.99	13.28
Heartwood	10.29	9.58

Table 6. Extractives in Aspen and Balsam Poplar.

	BALSAM POPLAR %	ASPEN %
I. Alcohol and Benzene		
Bark	18.62	19.33
Sapwood	2.82	3.21
Heartwood	2.26	2.61
II. Pet. Ether		
Bark	3.14	1.27
Sapwood	1.43	0.87
Heartwood	1.79	1.07
III. Water		
Sapwood	2.87	2.07
Heartwood	2.25	2.25
IV. PH Water Extracts		
Sapwood	7.0	7.3
Heartwood	8.2	7.0

Within the tree variability of both aspen and balsam poplar is a very important observation which might be helpful in the understanding of physical and mechanical properties of forest products manufactured from both species. Accordingly, we have done a detailed analysis of both species and studied the segmental variation of specific gravity, moisture content, fibre length, vessel length and vessel segments. All of these parameters varied with age of the tree. The most significant variation between aspen and black poplar was recorded in the level of moisture content. Balsam poplar moisture content of mid-tree section (all trees were segmented to nine segments according to the age of the tree) were extremely high and significantly higher than in the mid-section of aspen trees (Section 5 and 6 balsam poplar 117.9% and 1369%: Aspen section 5 and 6 73.8% and 67.1% respectively). The variability in moisture content within the species is also very important as it might influence the processing parameters, flake formation uniformity and thus surface features of wafers.

Aspen as compared with balsam poplar is a more uniform species. Moisture variation within aspen is quite uniform (range of 18.8% to 73.8% MC), whereas in balsam poplar there is much more of a variable from one segment to another (range of moisture content from 15.3% to 136.9%). The moisture content in mature tree segments of both species are also quite different. Balsam poplar between the 30-40% range is very close to fibre saturation point, whereas the aspen mature section moisture content is between 60-70% - a very uniform distribution of moisture in all aspen segments.

The results of segmental variation of moisture content, specific gravity and fibre/vessel dimensions are summarized in Tables 7 (balsam poplar) and Table 8 (aspen).

Another important parameter which which significantly varies within the tree and specifically between the studied species is specific gravity. Aspen

specific gravity range is from 0.340 to 0.433 from segment 1 to segment 9 - mature wood. The highest specific gravity of aspen trees was recorded in overmature segments 7 - 8 or at an annual ring of 80 to 120. In balsam poplar

Specific gravity is significantly lower, ranging from 0.272 near the pith to 0.308 at the annual ring segments 50 to 60. The over-mature segments (annual ring 100-115) have a significantly lower specific gravity as compared to the aspen over-mature segment. The combination of low specific gravity and high moisture content variation may be one of the major problems in controlling uniformity of water surfaces, as shown on the preliminary surface structure from scanning electron micrographs (Picture 2). This phenomenon will be studied in Phase II of this ongoing project.

Variation of fibre/vessel dimension within the series also represents uniformity of wood and will contribute to wafers quality. The fibre-length of balsam poplar is more uniform for all segments with recorded range of 0.626 mm to 1.161 mm. In aspen trees the fibre-length range is from 0.574 to 1.052. Vessel width is, however, the most important factor as it contributes to variation of specific gravity and surface characteristics of wafers. Aspen has smaller vessel width diameter throughout all segments as compared with balsam poplar. Consequently, aspen wafer surface is more uniformly smooth as compared with black poplar. These important features are the focus of current detailed investigation on the distribution of vessel/fibre length and width within the mature and juvenile wood segments.

Currently available data on mature aspen fibre-length, vessel-length and vessel-width variation are listed in Tables 9-11. Data on mature balsam poplar are summarized in Table 12 (Fibre-length variation), Table 13 (Vessel-length variation) and Table 14 (Vessel width variations). The frequency distribution curves for fibre length and vessel diameters for both species are shown in Figures 9 (Aspen) and Figure 10 (balsam poplar).

The statistical differences in anatomical features between aspen and balsam poplar were evaluated by scanning an electron micrograph and particle size image analyser. The sample of parameters and print summaries of surface analyses are attached in the Appendix. The systematic study is in progress and will be reported in the Phase Two Report.

Table 7. Variation of Balsam Poplar Properties
Tree Code: B1 - Segments: 1-114.

SECTION NUMBER	YEARS ANNUAL RINGS SEGMENT	S.G.	M.C. %	FIBRE LENGTH mm	VESSEL LENGTH mm	VESSEL WIDTH mm
1	1-5	0.272	15.3	0.626	0.380	0.999
2	6-10	0.297	20.2	0.920	0.531	0.107
3	16-20	0.292	47.5	1.007	0.595	0.096
4	26-30	0.288	68.5	1.161	0.616	0.096
5	31-40	0.294	117.9	1.049	0.633	0.111
6	51-60	0.300	136.9	1.099	0.631	0.140
7	71-80	0.308	54.9	1.022	0.635	0.118
8	91-100	0.295	41.9	1.065	0.671	0.113
9	101-114	0.292	32.0	1.070	0.610	0.083

Table 8. Variation of Aspen Properties
Tree Code: A7-Segments: 1-119

SECTION NUMBER	YEARS ANNUAL RINGS SEGMENT	S.G.	M.C. %	FIBRE LENGTH mm	VESSEL LENGTH mm	VESSEL WIDTH mm
1	1-5	0.340	18.8	0.574	0.384	0.063
2	6-10	0.364	21.8	0.596	0.444	0.073
3	16-20	0.373	30.9	0.784	0.535	0.071
4	26-30	0.398	53.1	0.868	0.575	0.061
5	36-40	0.412	73.8	1.052	0.647	0.075
6	51-60	0.396	67.1	0.881	0.551	0.075
7	71-80	0.410	73.5	0.860	0.571	0.092
8	91-100	0.425	71.1	0.914	0.565	0.081
9	101-119	0.433	61.9	0.980	0.707	0.069

Table 9. Mature Aspen. Fibre Length Variation.
Slide Code/ID: A1-119-FIBLEN

FIBRE NUMBER	LENGTH mm	FIBRE NUMBER	LENGTH mm
1	0.918	21	1.180
2	0.927	22	1.088
3	0.917	23	1.006
4	1.201	24	0.927
5	0.948	25	0.886
6	0.931	26	0.803
7	0.998	27	0.646
8	0.827	28	1.030
9	1.293	29	1.001
10	0.653	30	1.210
11	0.890	31	1.147
12	0.823	32	1.030
13	1.150	33	0.825
14	1.066	34	0.656
15	0.887	35	1.140
16	1.169	36	0.887
17	0.919	37	1.131
18	1.243	38	1.154
19	0.559	39	1.272
20	1.221	40	0.655

LENGTH MEAN OF 40 FIBRES = 0.98 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.19.

Table 10. Mature Aspen. Vessel Length Variation
Slide Code/I.D.:A1-119 VESLEN

VESSEL NUMBER	LENGTH mm	VESSEL NUMBER	LENGTH mm
1	0.652	16	0.727
2	0.650	17	0.661
3	0.747	18	0.826
4	0.763	19	0.814
5	0.721	20	0.633
6	0.827	21	0.744
7	0.687	22	0.654
8	0.752	23	0.656
9	0.832	24	0.832
10	0.632	25	0.771
11	0.580	26	0.705
12	0.761	27	0.652
13	0.628	28	0.505
14	0.589	29	0.755
15	0.779	30	0.680

LENGTH MEAN OF 30 FIBRES = 0.707 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.083

Table 10. Mature Aspen. Vessel Width Variation
Slide Code/ID: A1-119 VESWID

VESSEL NUMBER	LENGTH mm	VESSEL NUMBER	LENGTH mm
1	0.050	16	0.072
2	0.050	17	0.045
3	0.060	18	0.064
4	0.050	19	0.055
5	0.084	20	0.091
6	0.073	21	0.063
7	0.055	22	0.057
8	0.092	23	0.060
9	0.063	24	0.068
10	0.075	25	0.087
11	0.076	26	0.090
12	0.046	27	0.054
13	0.095	28	0.059
14	0.060	29	0.084
15	0.086	30	0.094

LENGTH MEAN OF 30 FIBRES = 0.069 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.016

Table 12. Mature Balsam Poplar. Fibre Length Variation
Slide Code/ID: B1-114 FIBLEN

FIBRE NUMBER	LENGTH mm	FIBRE NUMBER	LENGTH mm
1	1.000	21	0.759
2	0.926	22	1.272
3	1.298	23	0.942
4	0.876	24	0.729
5	0.962	25	0.873
6	1.182	26	1.089
7	1.279	27	1.424
8	1.024	28	1.204
9	1.103	29	1.040
10	1.076	30	1.089
11	1.008	31	1.189
12	1.045	32	1.028
13	1.054	33	1.130
14	1.036	34	0.896
15	1.118	35	1.360
16	1.144	36	0.777
17	1.092	37	1.011
18	1.358	38	1.169
19	0.938	39	1.225
20	0.798	40	1.262

LENGTH MEAN OF 40 FIBRES = 1.07 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.17

Table 13. Mature Balsam Poplar. Vessel Length Variation.
Slide Code/ID: B1-114 VESLEN

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16	1.144	36	0.777
17	1.092	37	1.011
18	1.358	38	1.169
19	0.938	39	1.225
20	0.798	40	1.262

LENGTH MEAN OF 40 FIBRES = 1.07 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.17

Table 13. Mature Balsam Poplar. Vessel Length Variation.
Slide Code/ID: B1-114 VESLEN

FIBRE NUMBER	LENGTH mm	FIBRE NUMBER	LENGTH mm
1	0.620	16	0.564
2	0.583	17	0.545
3	0.686	18	0.676
4	0.586	19	0.587
5	0.449	20	0.566
6	0.749	21	0.629
7	0.801	22	0.636
8	0.723	23	0.660
9	0.521	24	0.508
10	0.829	25	0.521
11	0.493	26	0.713
12	0.002	27	0.766
13	0.440	28	0.732
14	0.610	29	0.717
15	0.716	30	0.671

LENGTH MEAN OF 30 FIBRES = 0.61 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.153

Table 14. Mature Balsam Poplar. Vessel Width Variation
Slide Code/ID: B1-114 VESWID

FIBRE NUMBER	LENGTH mm	FIBRE NUMBER	LENGTH mm
1	0.086	16	0.073
2	0.110	17	0.096
3	0.056	18	0.070
4	0.066	19	0.109
5	0.104	20	0.109
6	0.076	21	0.103
7	0.106	22	0.052
8	0.083	23	0.065
9	0.056	24	0.091
10	0.056	25	0.105
11	0.076	26	0.088
12	0.073	27	0.070
13	0.067	28	0.091
14	0.059	29	0.078
15	0.101	30	0.104

LENGTH MEAN OF 30 FIBRES = 0.083 mm
STANDARD DEVIATION FOR THE LENGTHS IS 0.019

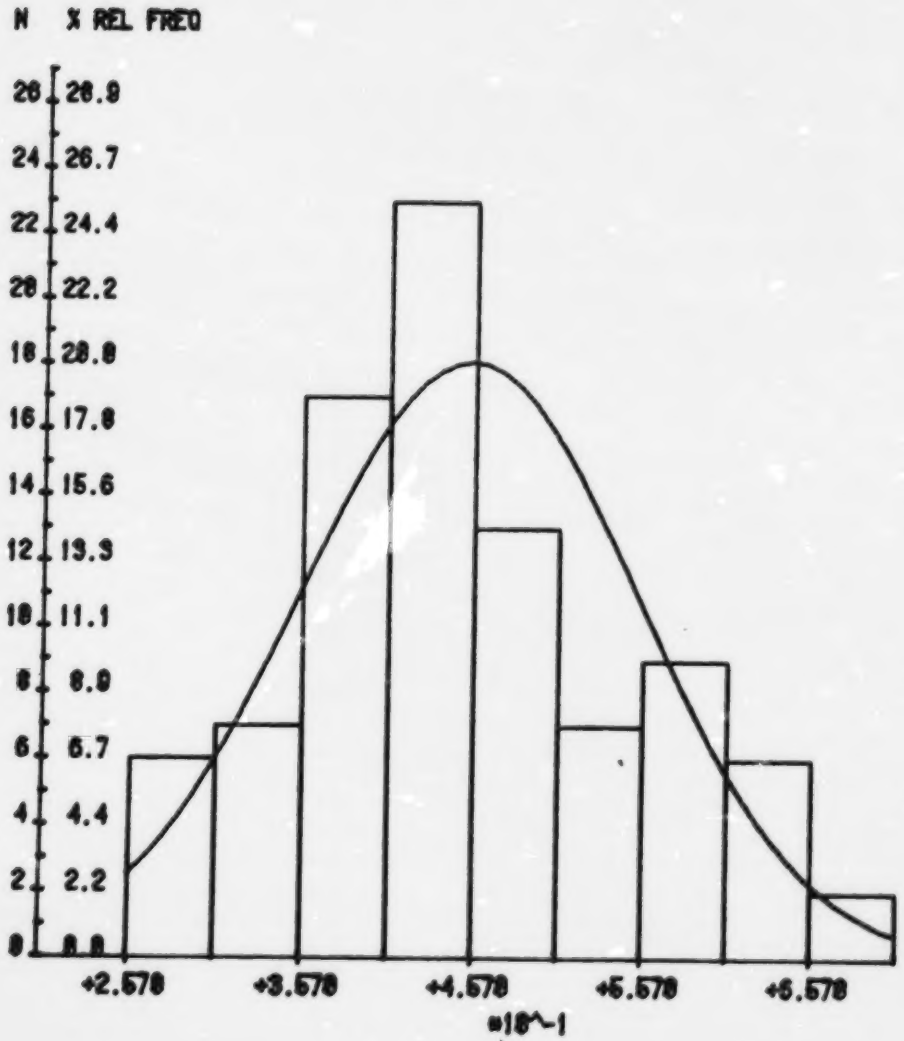

Figure 6. Relative Frequency Distribution Curve; Aspen Juvenile Wood Vessel Length

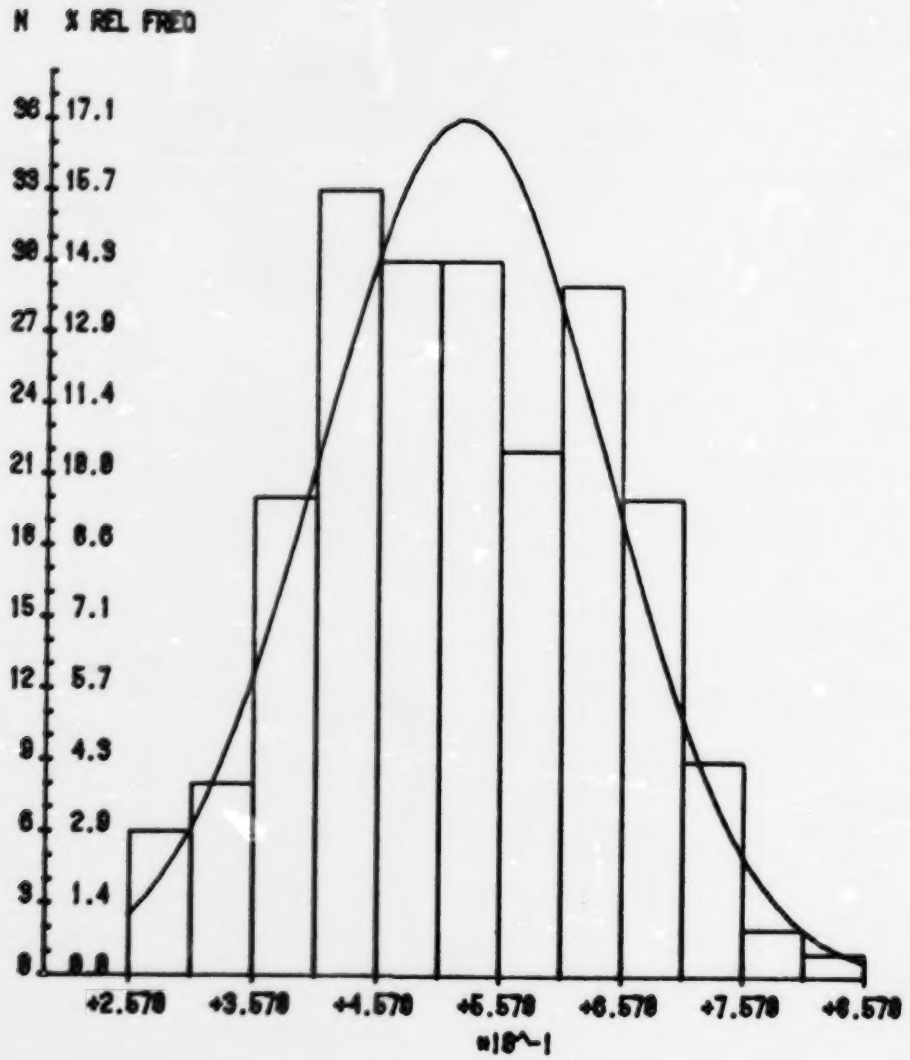

Figure 10. Relative Frequency Distribution Curve.
Aspen Nature Wood Vessel Length.

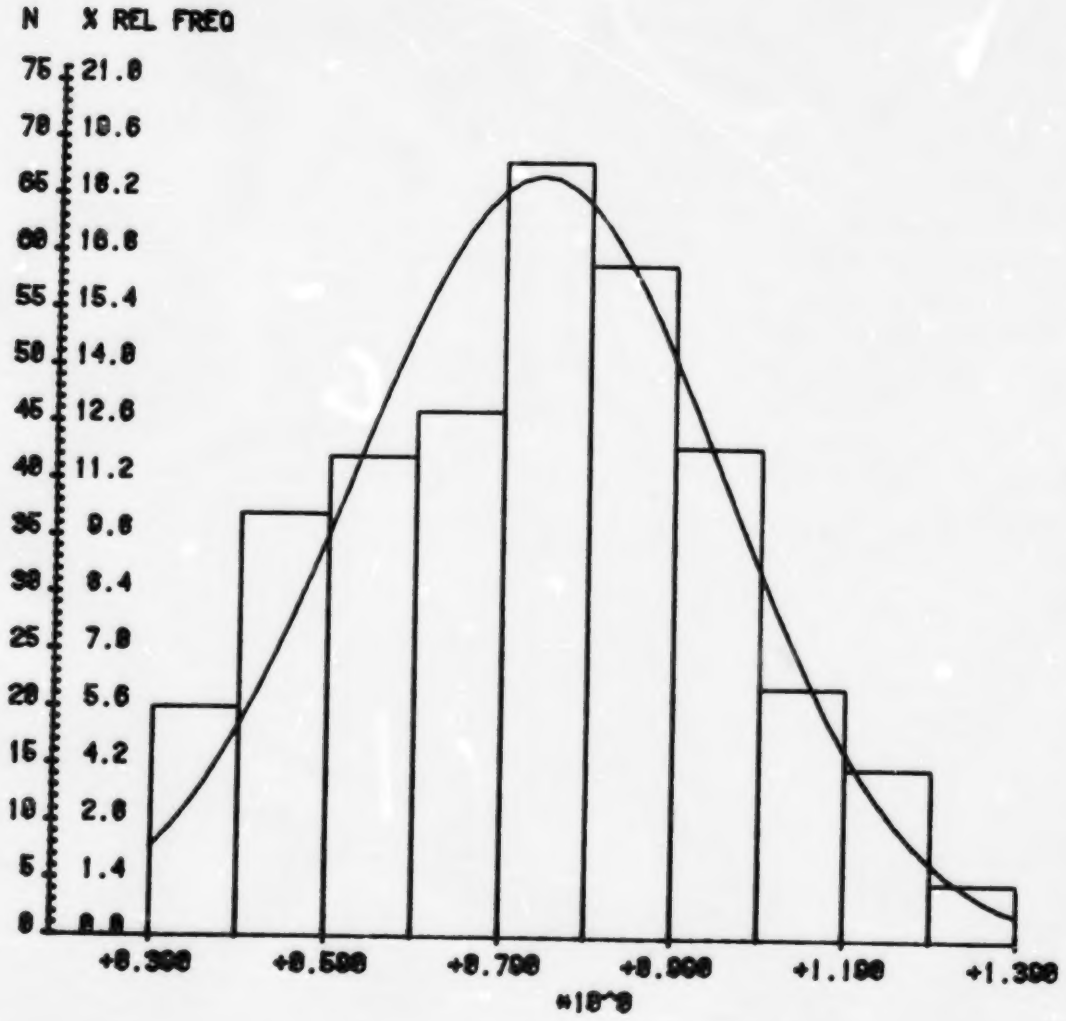

Figure 11. Relative Frequency Distribution Curve. Aspen Fibre Length.